INTERMEDIATE/SECONDARY ARTICLE: Measuring Electricity

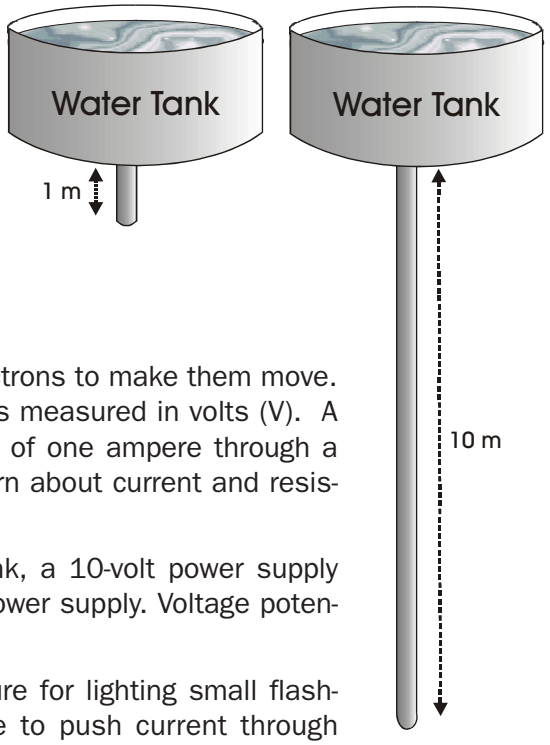
We use electricity for hundreds of tasks every day. It makes our lives productive and enjoyable, yet it remains a mysterious force to most of us. Understanding electricity and how it is measured is confusing because we cannot see it. We are familiar with terms such as watt, volt, and amp, but most of us do not have a clear understanding of these terms. We buy a 60-watt lightbulb, a tool that requires 120 volts, or a vacuum cleaner that uses 8.8 amps, and don't really think about what those measurements mean. We are confident that when we plug them in, they will work.

It is important to understand electricity, because we rely on it for so many things. Electricity is the flow of electrons. Using the flow of water as an analogy can make concepts of electricity easier to understand. The flow of electrons in a circuit is similar to water running through a hose.

If you could look into a hose at a given point, you would see that a certain amount of water passes that point each second. The amount of water depends on how much pressure is being applied—how hard the water is being pushed. It also depends on the diameter of the hose. The more forceful the pressure and the larger the diameter of the hose, the more water passes each second. The flow of electrons through a wire depends on the electrical pressure pushing the electrons and on the cross-sectional area of the wire.

Voltage

The pressure that pushes electrons in an electrical circuit is called voltage. Using the water analogy, if a tank of water were suspended one meter above the ground with a one-centimeter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you. (If you jumped from a one-meter diving board, the force when you hit the water would not be too great. If you jumped from a 10-meter board, the force would be much greater.)



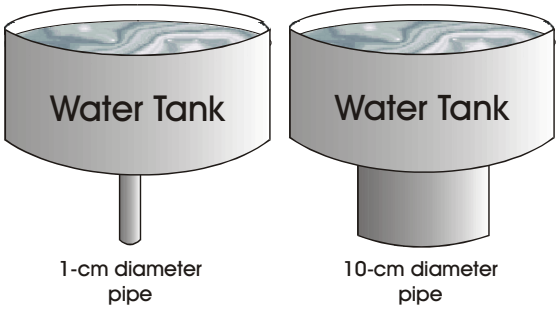
Voltage (V) is a measure of pressure, or electromotive force, applied to electrons to make them move. It is a measure of the strength of the electric current in a circuit. Voltage is measured in volts (V). A volt is the amount of electromotive force (emf) needed to push a current of one ampere through a resistance of one ohm. This definition will make more sense after you learn about current and resistance.

Just as the 10-meter tank applies greater pressure than the 1-meter tank, a 10-volt power supply (such as a battery) would apply greater electromotive force than a 1-volt power supply. Voltage potential is the electrical term that is analogous to water pressure.

AA batteries are 1.5-volt; they apply a small amount of voltage or pressure for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a potentially dangerous amount of voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous amount of voltage.

Current

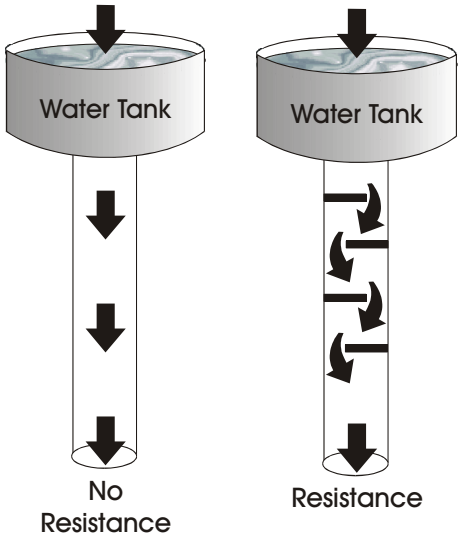
The flow of electrons can be compared to the flow of molecules of water. The water current is the number of molecules flowing past a fixed point; electrical current is the number of electrons flowing past a fixed point. Electrical current is defined as electrons flowing between two points having a difference in voltage potential. Current is measured in amperes or amps (A). One ampere is 6.25×10^{18} electrons per second passing through a circuit.



With water, as the diameter of the pipe increases, so does the amount of water that can flow through it. With electricity, a conducting wire is the pipe. As the cross-sectional area of the wire increases, so does the amount of electric current (number of electrons) that can flow through it.

Resistance

Resistance is a property that slows the flow of electrons—the current. Using the water analogy, resistance is an impediment to water flow. It could be a smaller pipe or fins on the inside of a pipe. In electrical terms, the resistance of a conducting wire is dependent on the metal used to make the wire, and the diameter of the wire. Copper, aluminum, and silver—common metals used in conducting wires—all have different resistance properties. Resistance is a characteristic property of a conducting material.



Resistance is measured in units called ohms (Ω). There are electrical devices, called resistors, designed with specific resistance that can be placed in circuits to reduce or control the flow of the current. Every electrical appliance contributes resistance to a circuit, as well. Any appliance or device placed within a circuit to do work is called a load. The lightbulb in a flashlight is a load. A television plugged into a wall outlet is a load. Every load introduces resistance in a circuit.

Ohm's Law

George Ohm, a German physicist, made an important discovery about electricity in the early 19th century. He found that in many materials, especially metals, the current that flows through a material is proportional to the voltage across the material. In the substances he tested, he found that if he doubled the voltage (V), the current (A) also doubled. If he reduced the voltage by half, the current dropped by half. The resistance (Ω) of the material remained the same whether the voltage and current increased or decreased. This relationship is called Ohm's Law, and can be written in three simple formulas. If you know any two of the measurements, you can calculate the third using these formulas:

voltage (volts) = current (amperes) x resistance (ohms) **or** **V = A x Ω**

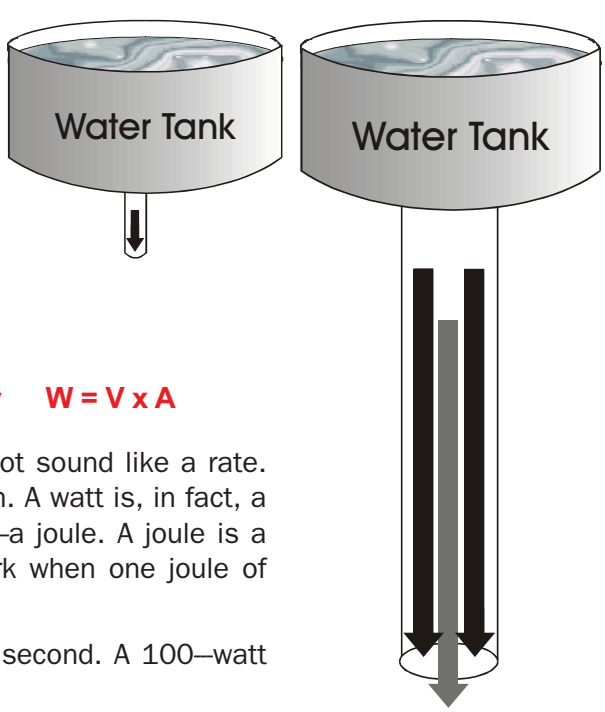
current (amperes) = voltage (volts) / resistance (ohms) **or** **A = V / Ω**

resistance (ohms) = voltage (volts) / current (amperes) **or** **Ω = V / A**

Electrical Power

Power is a measure of the rate of doing work or the rate at which energy is converted. Electrical power is the rate at which electricity is produced or consumed. Using the water analogy, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work.

A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater force (voltage potential) than water at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from a height of 10 meters.



Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start a device or operate a load for one second. Electrical power is measured in watts (W). The formula for power that quantifies this relationship is:

power (watts) = voltage (volts) x current (amperes) **or** **W = V x A**

Measuring electrical power can be confusing because a watt does not sound like a rate. Usually we think of rates as ratios—miles per hour or miles per gallon. A watt is, in fact, a ratio; you must learn about another measurement to understand it—a joule. A joule is a measurement of work performed. One watt is the rate of doing work when one joule of energy is used in one second (1 watt = 1 joule/second).

A 50–watt lightbulb uses electrical power at a rate of 50 joules per second. A 100–watt lightbulb uses electrical power at the rate of 100 joules per second.